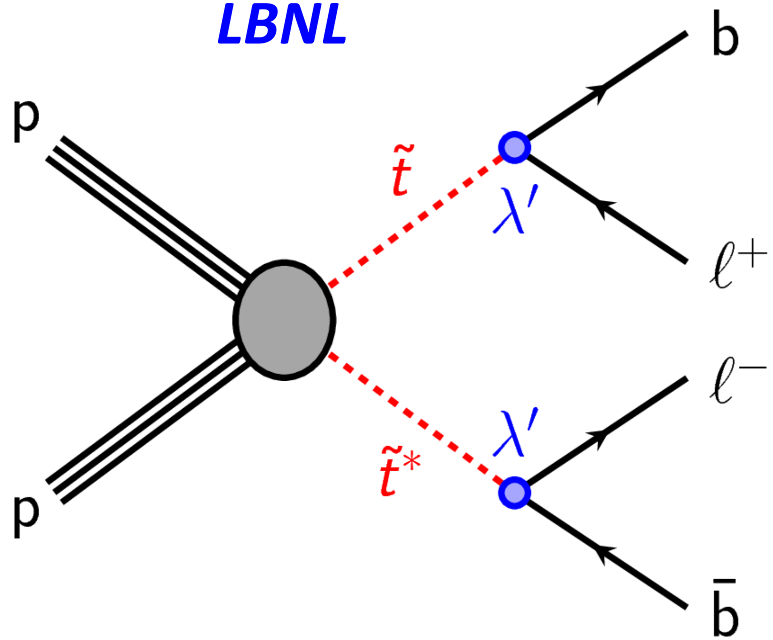
Search for scalar top with R-Parity Violating decay (ATLAS-CONF-2015-015)

Evelyn Thomson, Brett Jackson, Leigh Schaefer

University of Pennsylvania

Zach Marshall

LBNL



Overview

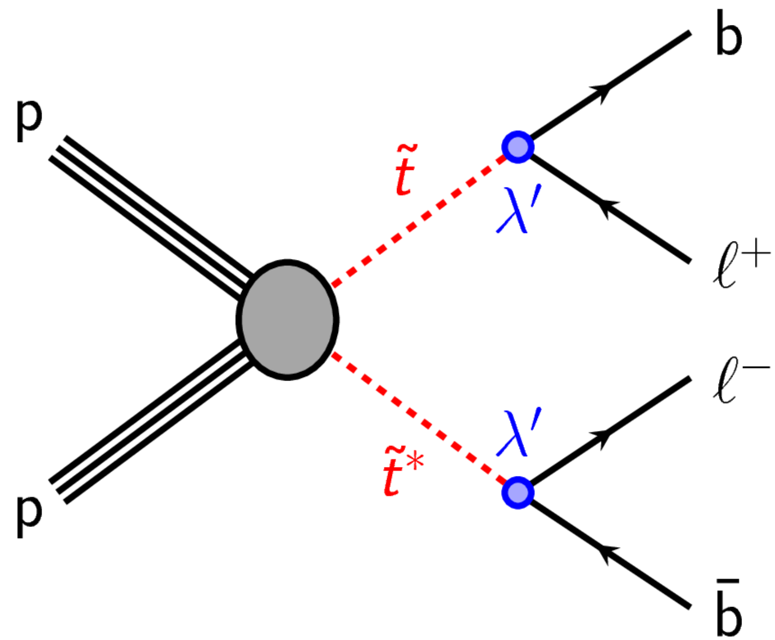
Selection

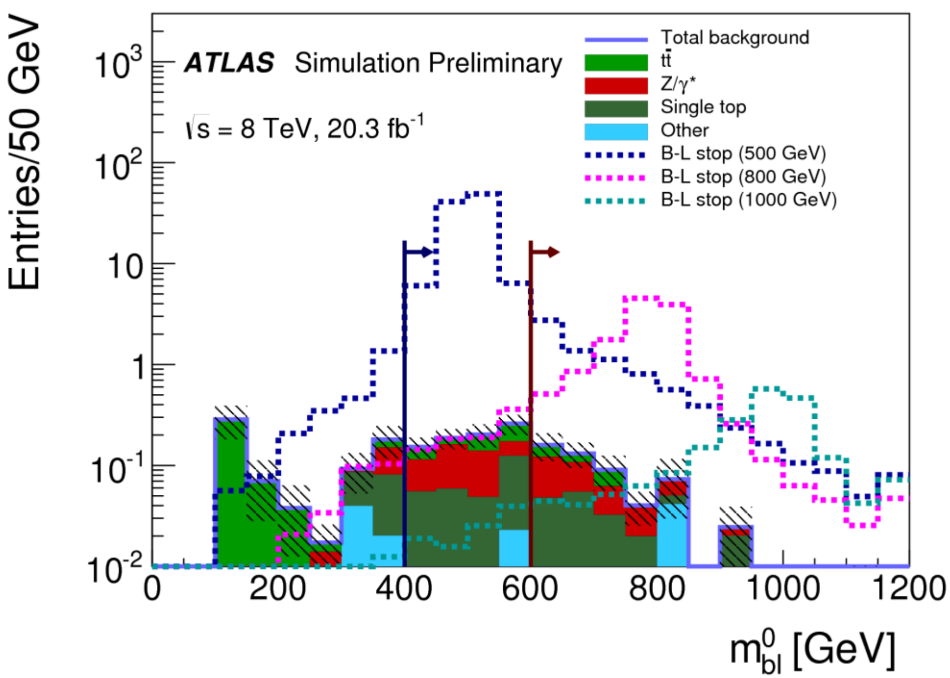
- **2 leptons ee, eμ, μμ**
- **2 b-jets**
- **Resonance: lepton + b-jet**

Backgrounds

- **t tbar, Wt, Z/γ*+jets**

Results from Run 1





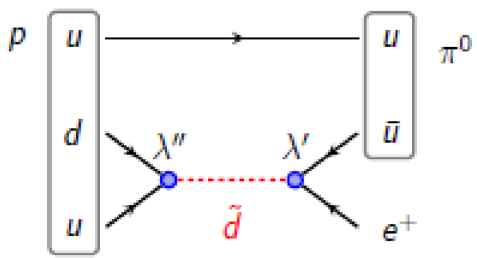
SUSY and proton decay

$R=(-1)^{3(B-L)+2s}$

OR

Assume R-Parity conservation

- Proton stable ($p \not\to e^+ \pi^0$) since RPC forbids both baryon and lepton number violation

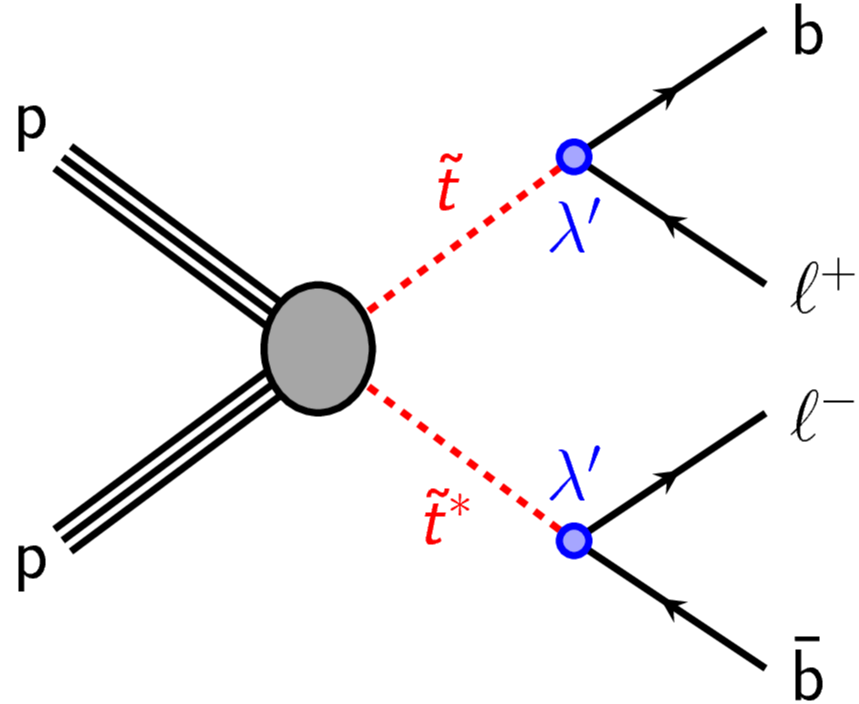


- Lightest SUSY particle (LSP) is also stable
  - Neutral LSP is a good dark matter candidate
  - Conventional SUSY signatures have missing momentum at LHC

Add a new U(1) B-L symmetry

- Proton still stable since only lepton number violation allowed
- "Collider" LSP has lepton number violating decay
  - No missing momentum!
  - Unique signature if scalar top decays to a charged lepton and b quark
- Gravitino LSP decays slowly enough to be dark matter
- Symmetry spontaneously broken by RH sneutrino to give massive B-L gauge boson (TeV)

B-L model



Stop pair production abundant through usual RPC processes

Stop LSP decays promptly through RPV process

- ***Stop LSP decay:* Z. Marshall, B.A. Ovrut, A. Purves, S. Spinner 1402.5434, 1401.7989**
- ***Minimal SUSY B-L:* B. A. Ovrut, A. Purves, S. Spinner 1503.01473, 1412.6103, 1203.1325**
- ***Minimal RPV:* P. Fileviez Perez, S. Spinner 1308.0524, 1201.5923;, 0904.2213, 0811.3424; with V. Barger 0812.3661; with L.L. Everett 0906.4095**
- ***Heterotic string theory:* M. Ambroso, B.A. Ovrut 1005.5392, 0904.4509; V. Braun, Y.-H. He, B.A. Ovrut hep-th/0602073; with T. Pantev 0512177, 0501070**

Stop mass (GeV)	Pair production xs (fb)	
	√s = 8 TeV	√s=13 TeV
500	86 ± 13	518 ± 69
800	2.9 ± 0.6	28 ± 4
1000	0.44± 0.12	6.4 ± 1.0
1400	-	0.46± 0.10

M. Kramer et al. 1206.2892

C. Borschensky et al. 1407.5066

ATLAS detector

Triggers

- 93-98% efficient

Identify Muons

- Momentum resolution 5% at 500 GeV

Identify Electrons

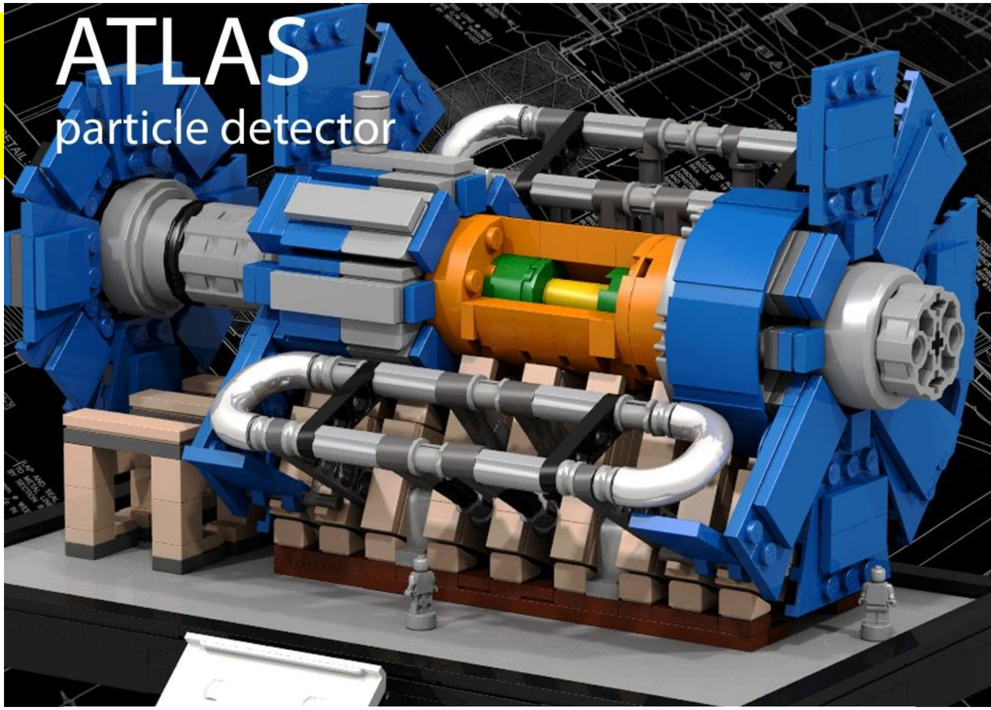
- Energy resolution $9\%/\sqrt{E}$

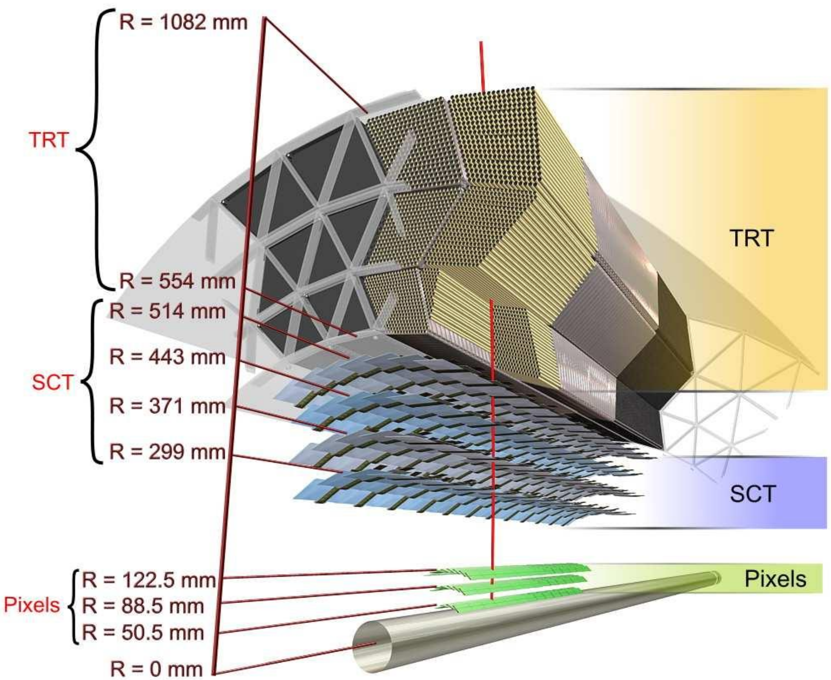
Anti-k_t Jets with R=0.4

- Energy resolution $45\%/\sqrt{E}$

Identify b-jets

- 80% efficiency per b-jet, rejection factor 25





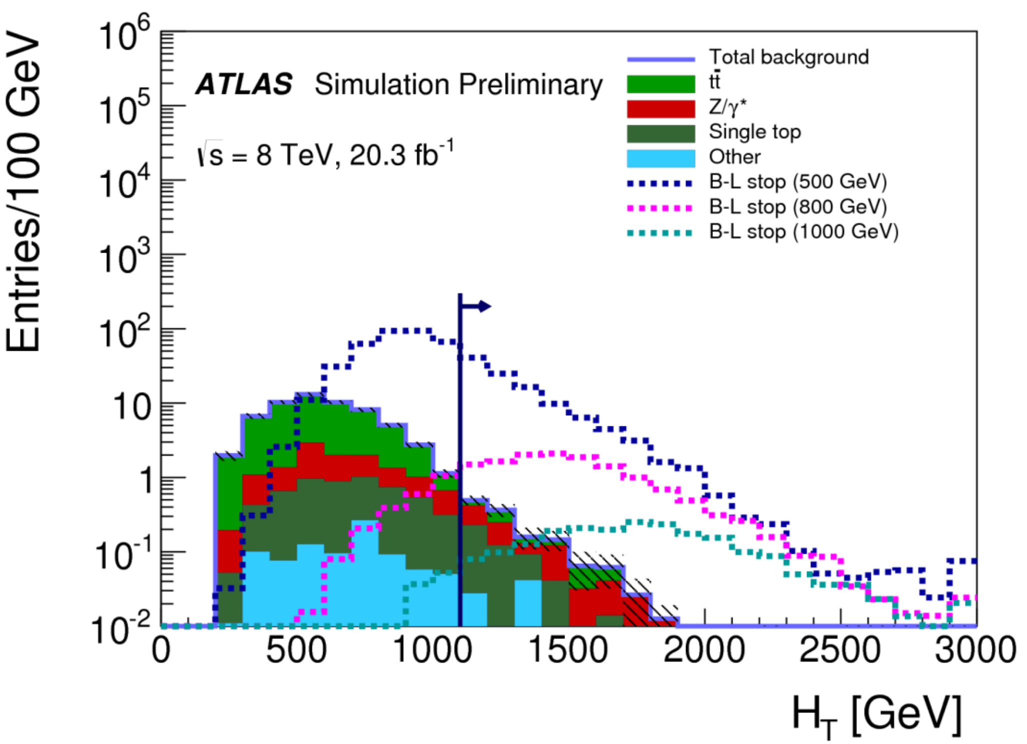
Selection

Require two leptons (electrons or muons) and two b-jets, all with $p_T > 40$ GeV

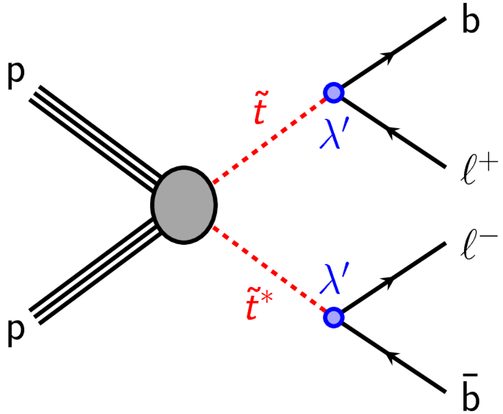
Selection	$m_{\tilde{t}} = 500$ GeV	$m_{\tilde{t}} = 800$ GeV	$m_{\tilde{t}} = 1000$ GeV
$\sigma \cdot L$	1750 ± 260	59 ± 12	8.9 ± 2.5
$bb\ell\ell$	624 ± 4	19.65 ± 0.18	2.68 ± 0.05
Z veto	619 ± 4	19.62 ± 0.18	2.68 ± 0.05
$H_T \geq 1100$ GeV	122.9 ± 1.8	16.01 ± 0.17	2.50 ± 0.04
$m_{b\ell}$ asymmetry ≤ 0.2	112.8 ± 1.7	14.00 ± 0.15	2.11 ± 0.04
$m_{b\ell} \geq 400$ GeV	110.3 ± 1.7	13.74 ± 0.15	2.09 ± 0.04
$m_{b\ell} \geq 600$ GeV	7.7 ± 0.4	12.86 ± 0.15	1.99 ± 0.04

Main backgrounds from ttbar, Wt, Z/γ^* with associated b jets

- Reject Z+jets with cut on invariant mass of two same-flavor leptons around Z resonance
- Reduce all with H_T>1100 GeV, scalar sum of transverse momentum of two leading leptons and two leading b-jets

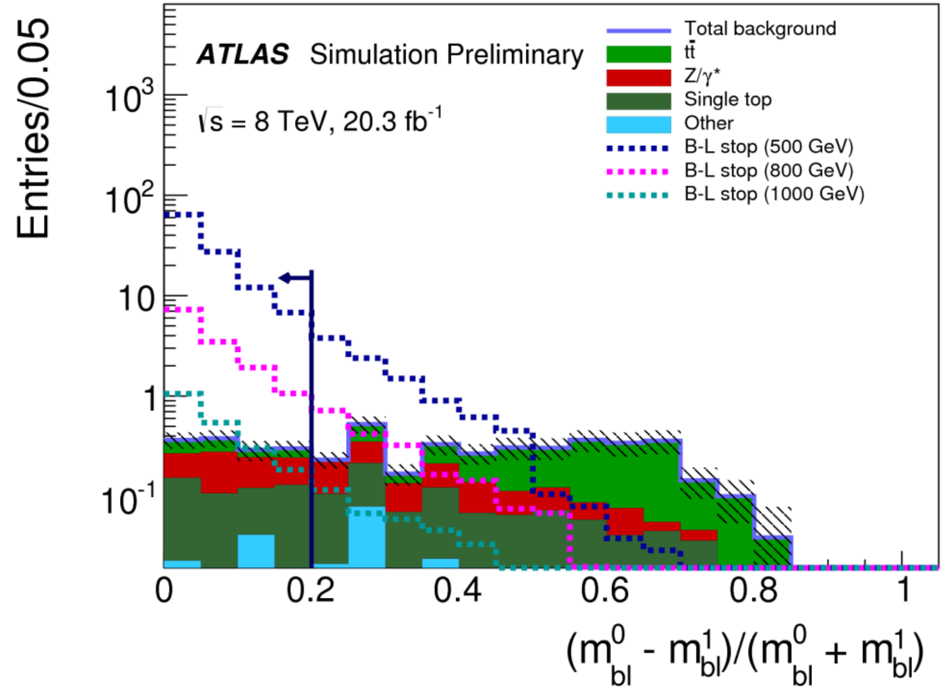


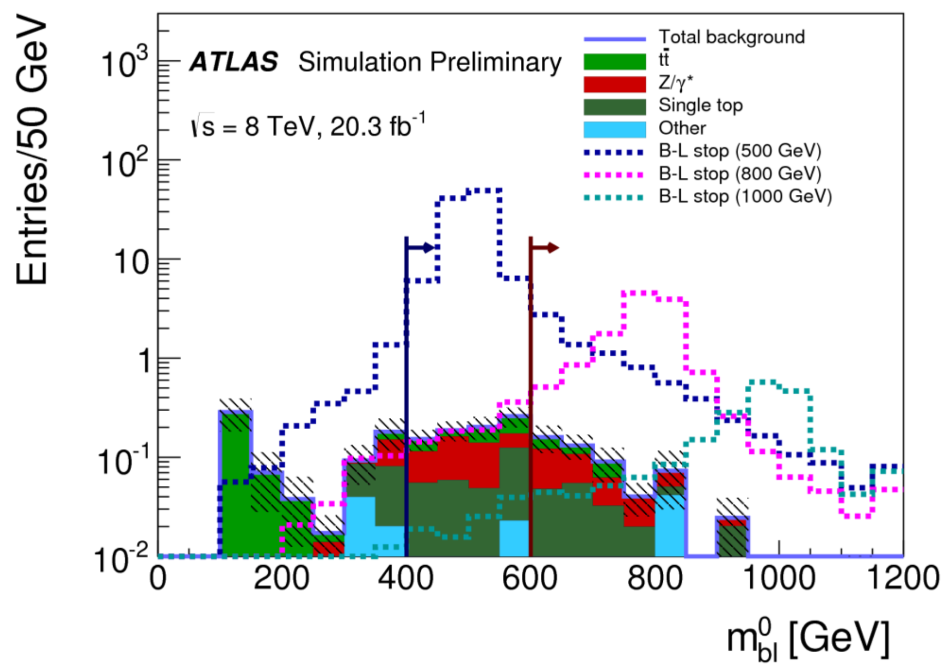
Selection II



Expect signal to have a resonance in lepton + b-jet invariant mass m_{bl} for each lepton and b-jet pair

- **Reject backgrounds with very different values of m_{bl} for each pair: asymmetry < 0.2**
- **Define two signal regions using highest m_{bl} > 400 or 600 GeV**

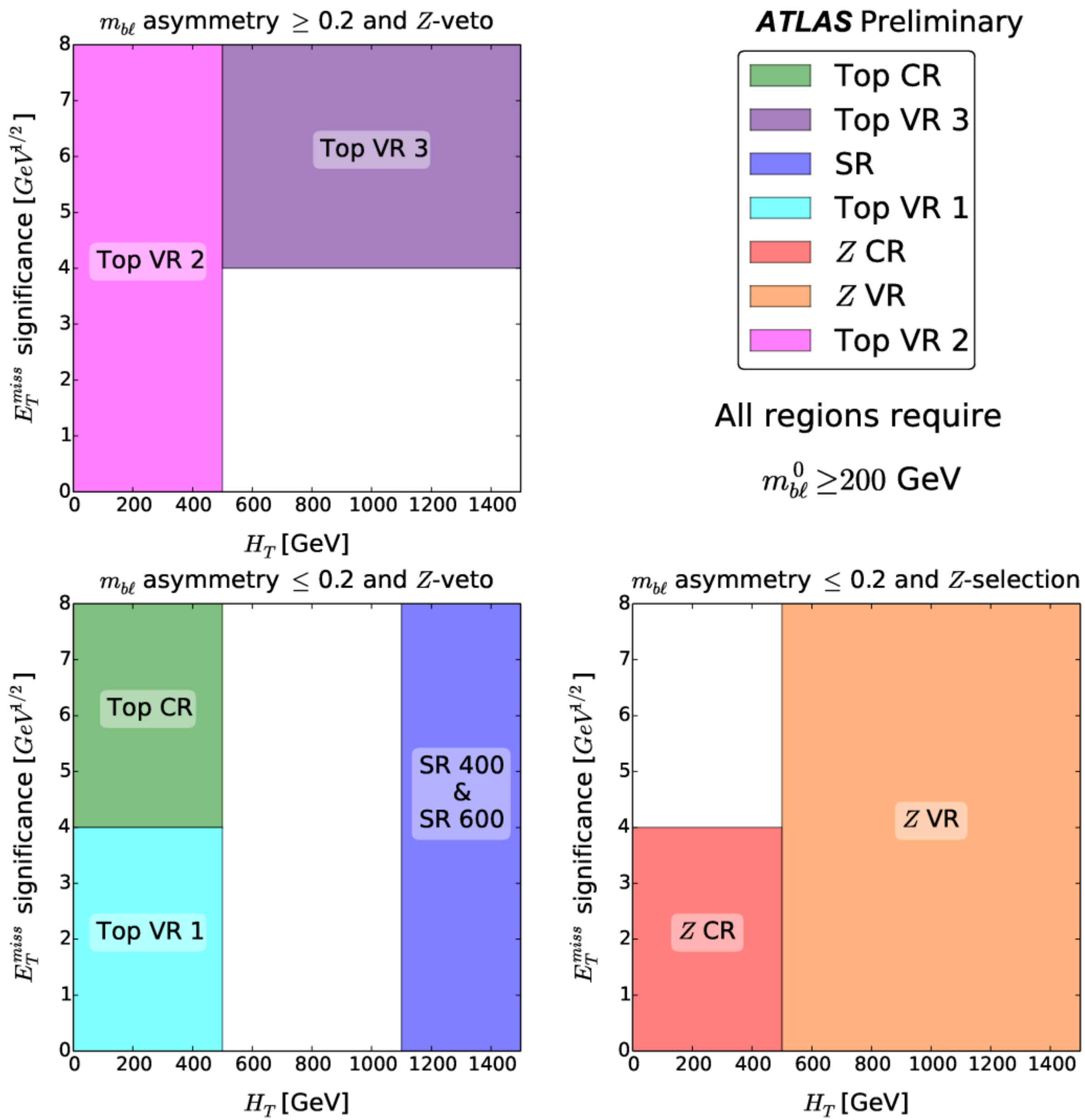




Background estimate

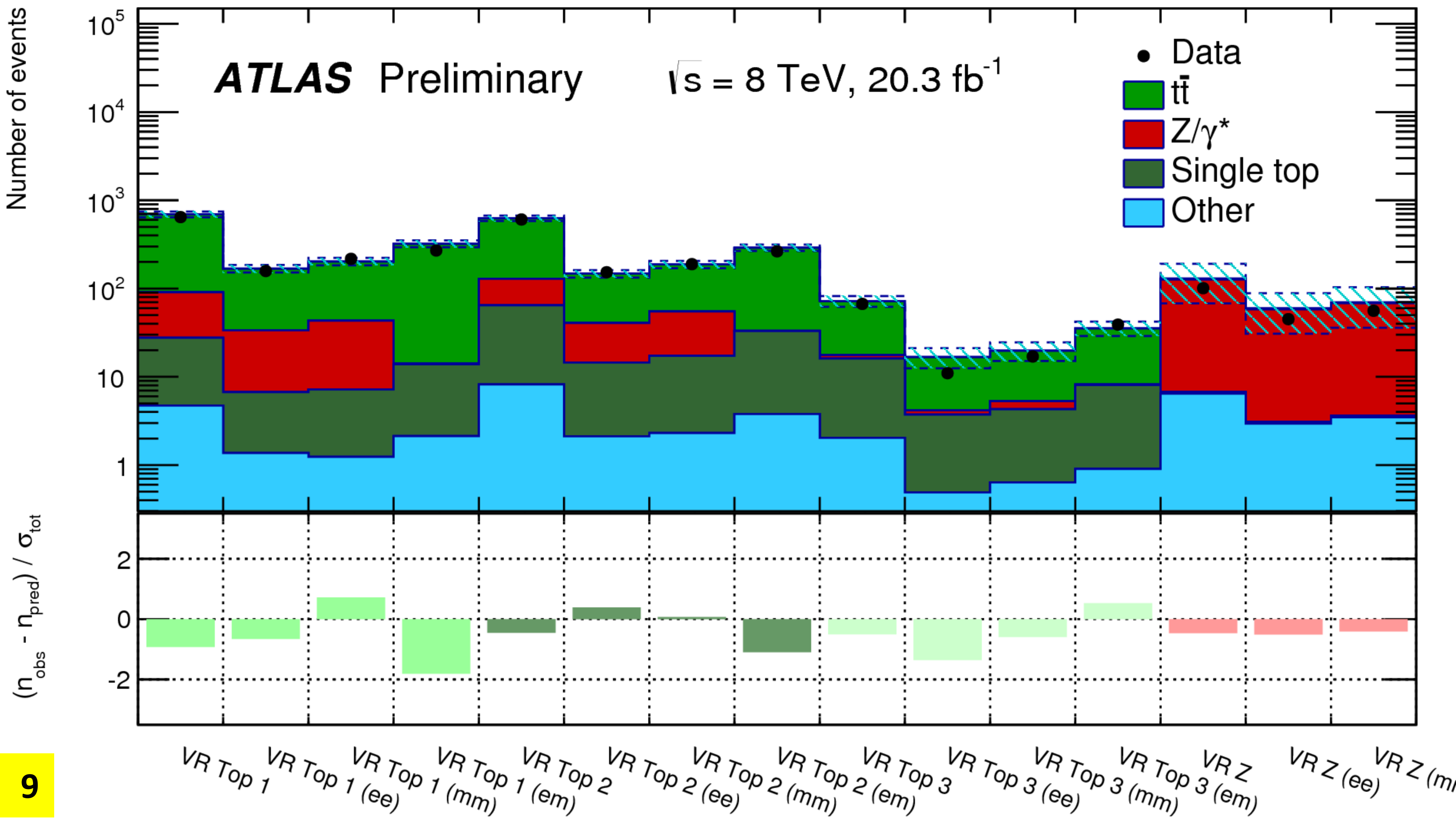
Dedicated control regions to set background rate for ttbar (Top CR) and Z+jets (Z CR)

Several validation regions, especially at higher H_T



Validation regions

Good agreement for fitted background estimate with data in validation regions (show all, ee, μμ, eμ for each region)

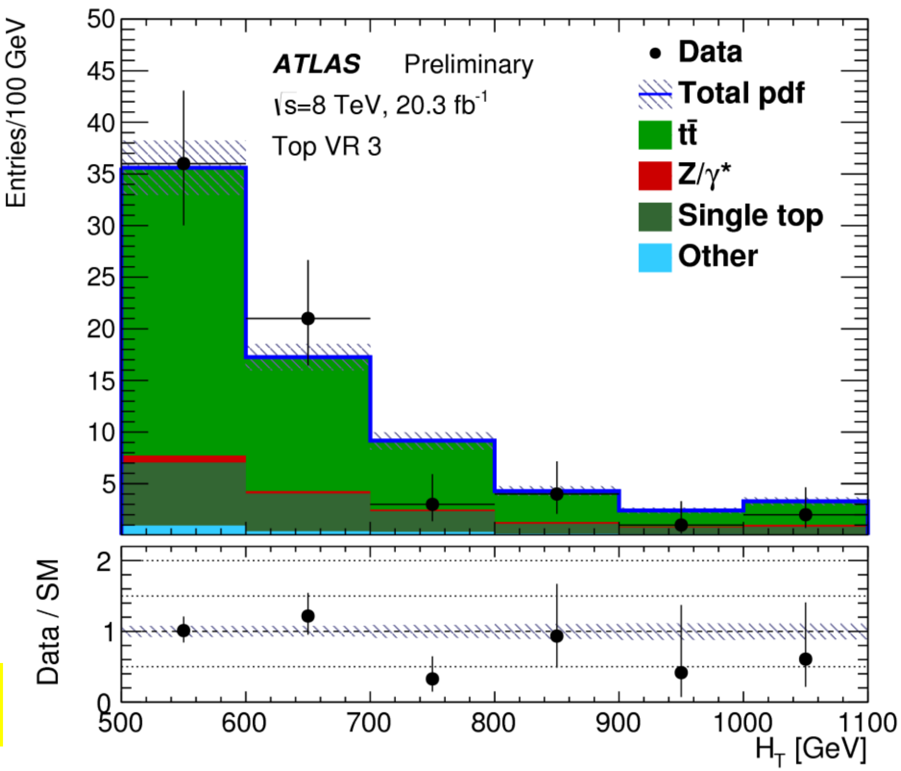


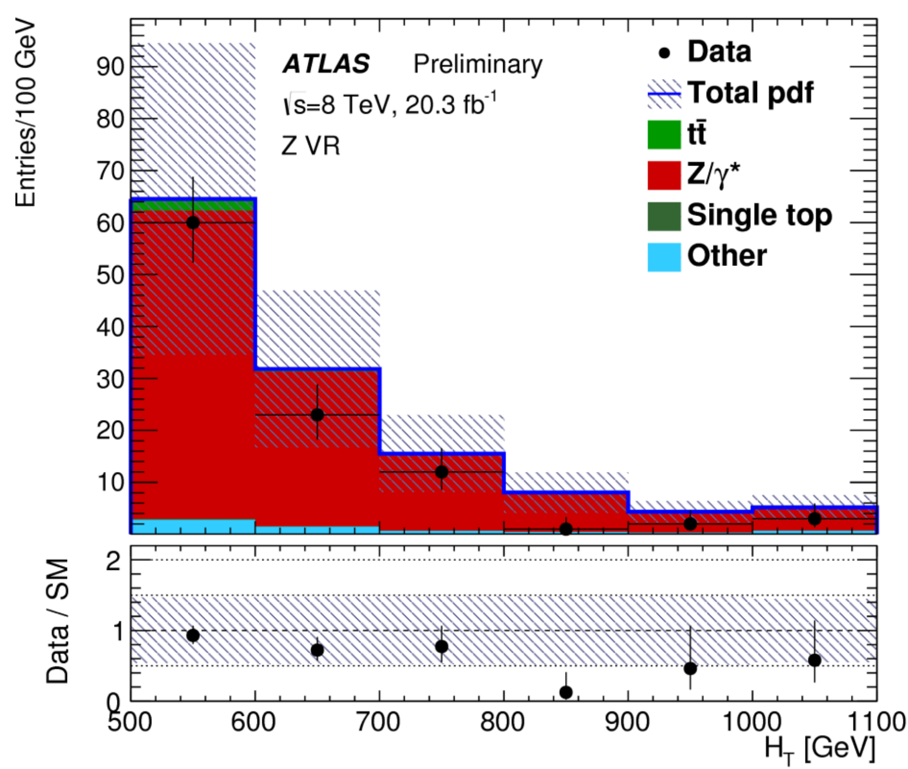
Background systematics

Validation regions at higher H_T

- **Good agreement for ttbar**
- **Add systematic uncertainty to cover overestimate for Z+jets**

Systematic Uncertainty (%)	SR 400	SR 600
JES	15	3
b-tagging	13	12
JER	5	1
Luminosity	1	1
H_T extrapolation	19	20
MC statistical	13	23
CR statistical	3	3
Wt cross section	2	2
Other theory	1	2

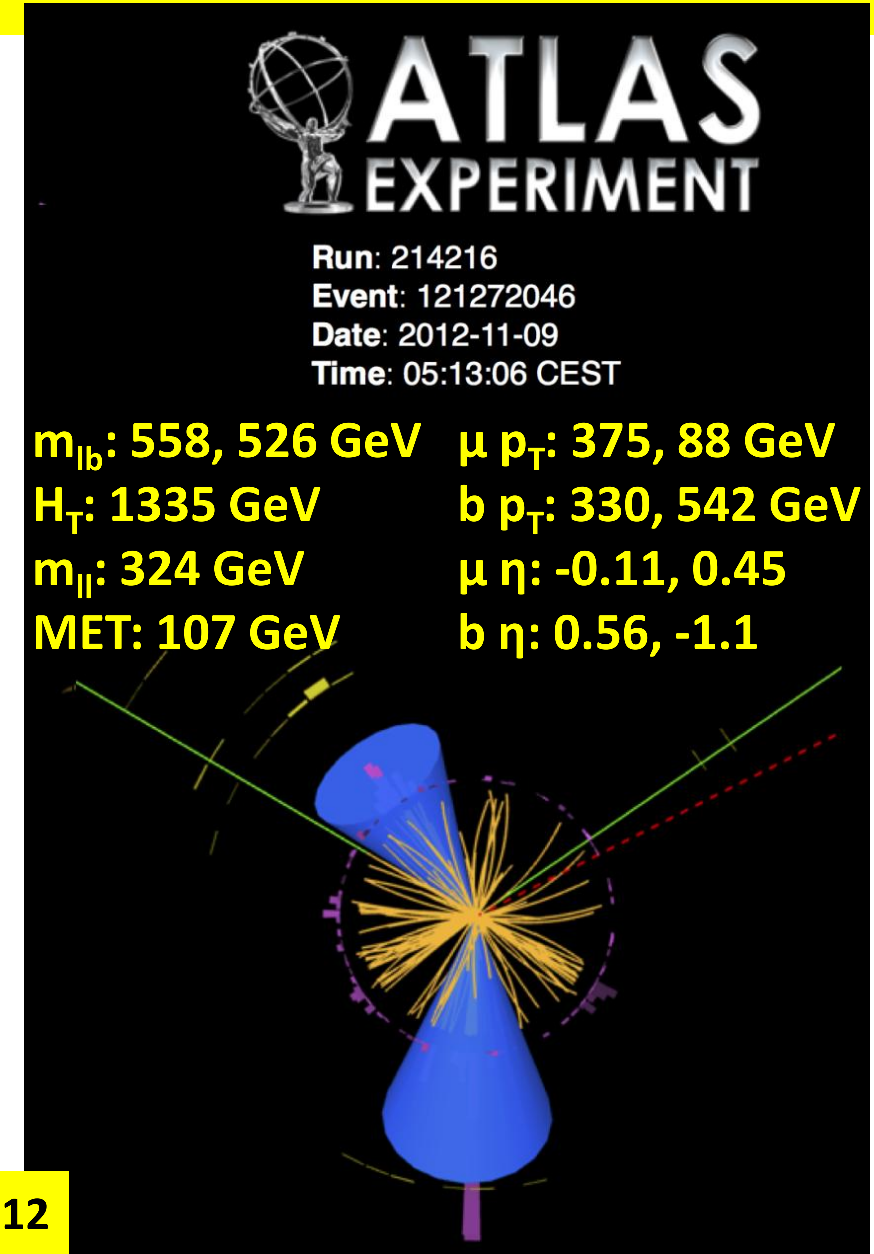




Results from Run 1

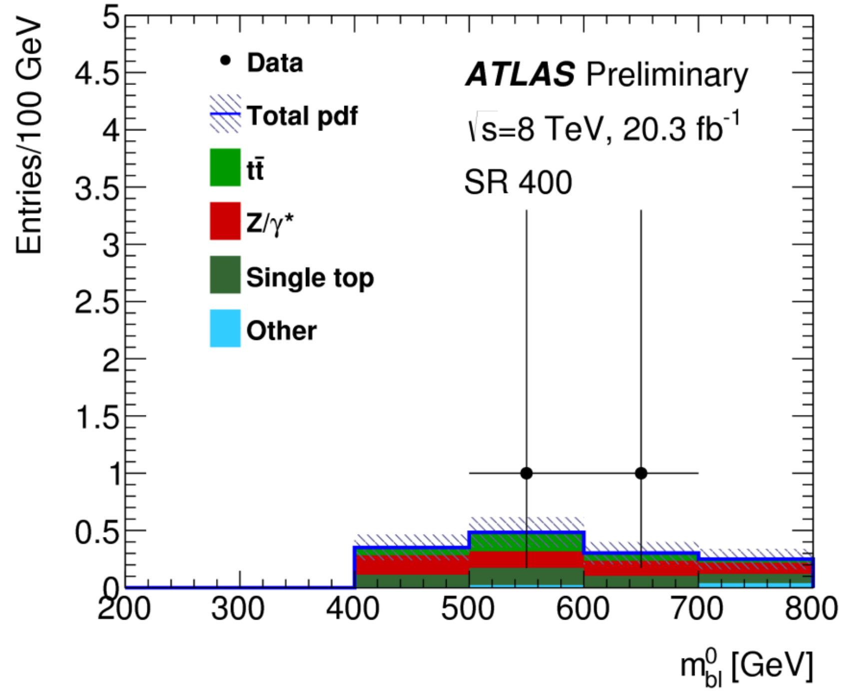
	SR 400	SR 400 ee	SR 400 $\mu\mu$	SR 400 $e\mu$
Observed	2	0	2	0
Fitted background	1.39 ± 0.35	0.36 ± 0.15	0.57 ± 0.20	0.45 ± 0.11
Fitted $t\bar{t}$	0.33 ± 0.09	0.07 ± 0.08	0.07 ± 0.02	0.19 ± 0.05
Fitted Z/γ^*+jets	0.54 ± 0.28	0.20 ± 0.10	0.35 ± 0.18	≤ 0.01
Single Top	0.44 ± 0.08	0.10 ± 0.03	0.11 ± 0.03	0.23 ± 0.05
Other	0.07 ± 0.04	≤ 0.01	0.04 ± 0.02	0.03 ± 0.03
Input SM	1.2	0.30	0.46	0.43
Input $t\bar{t}$	0.30	0.06	0.06	0.17
Input Z/γ^*+jets	0.38	0.14	0.24	0.00
Input single Top	0.44	0.10	0.11	0.23
Input other	0.07	0.00	0.04	0.03
σ_{vis} [fb]	0.23	0.11	0.26	0.11
Observed $N_{\mathrm{non-SM}}$	4.8	2.2	5.4	2.3
Expected $N_{\mathrm{non-SM}}$	$4.0^{+2.2}_{-1.1}$	$3.2^{+1.7}_{-1.1}$	$3.6^{+1.9}_{-1.5}$	$3.3^{+1.8}_{-1.3}$

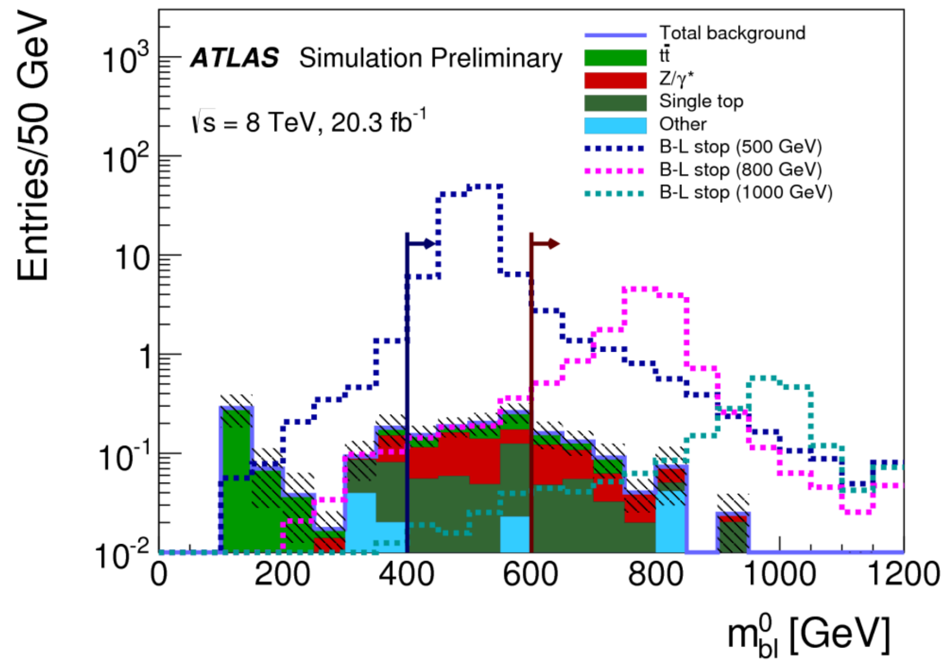
Results from Run 1



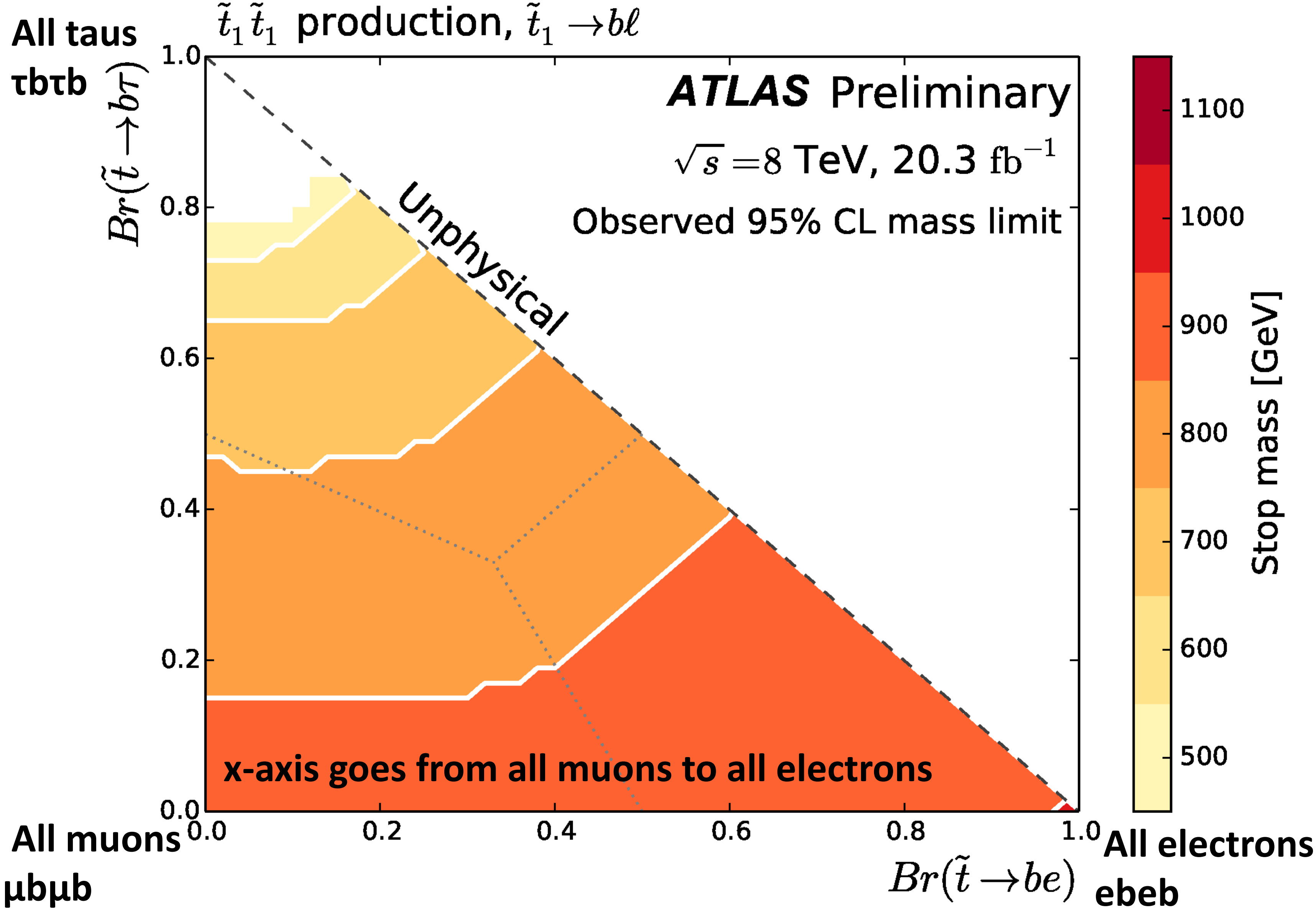
m_{lb}: 558, 526 GeV
H_T: 1335 GeV
m_{ll}: 324 GeV
MET: 107 GeV

μ p_T: 375, 88 GeV
b p_T: 330, 542 GeV
μ η: -0.11, 0.45
b η: 0.56, -1.1





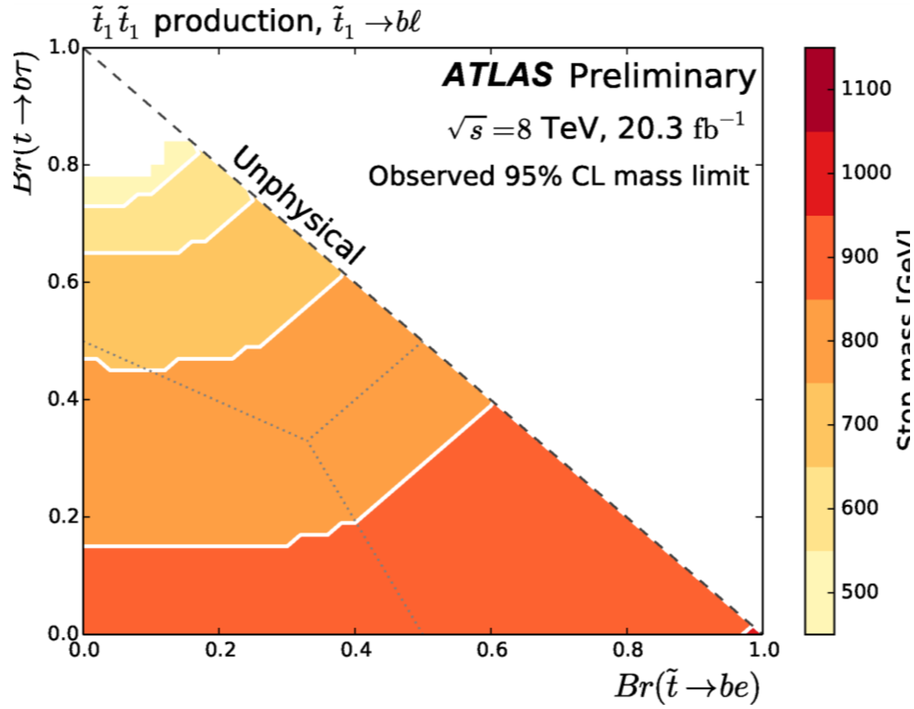
Limits

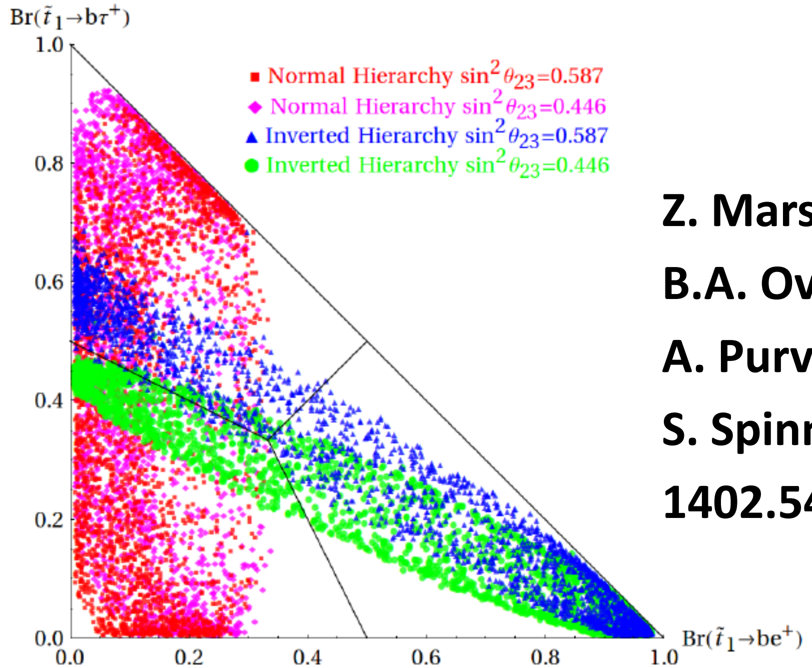


All taus
τbτb
$\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1 \rightarrow b\ell$
$Br(\tilde{t} \rightarrow b\tau)$
ATLAS Preliminary
$\sqrt{s}$ =8 TeV, 20.3 fb^{-1}
Observed 95% CL mass limit
Unphysical
x-axis goes from all muons to all electrons
All muons
μbμb
All electrons
ebeb
$Br(\tilde{t} \rightarrow be)$
Stop mass [GeV]
1100
1000
900
800
700
600
500
1.0
0.8
0.6
0.4
0.2
0.0

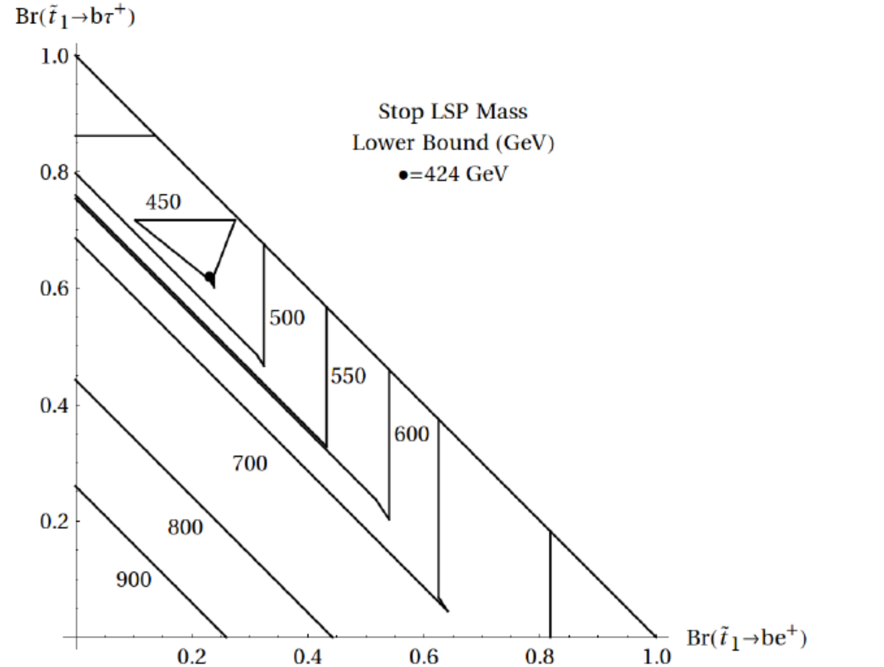
Interpretation

- Better reach than LQ searches for eejj and μμjj (no valley in middle)
- 3rd generation LQ search covers ττbb top corner
- Neutrino masses would be linked to collider physics through RPV





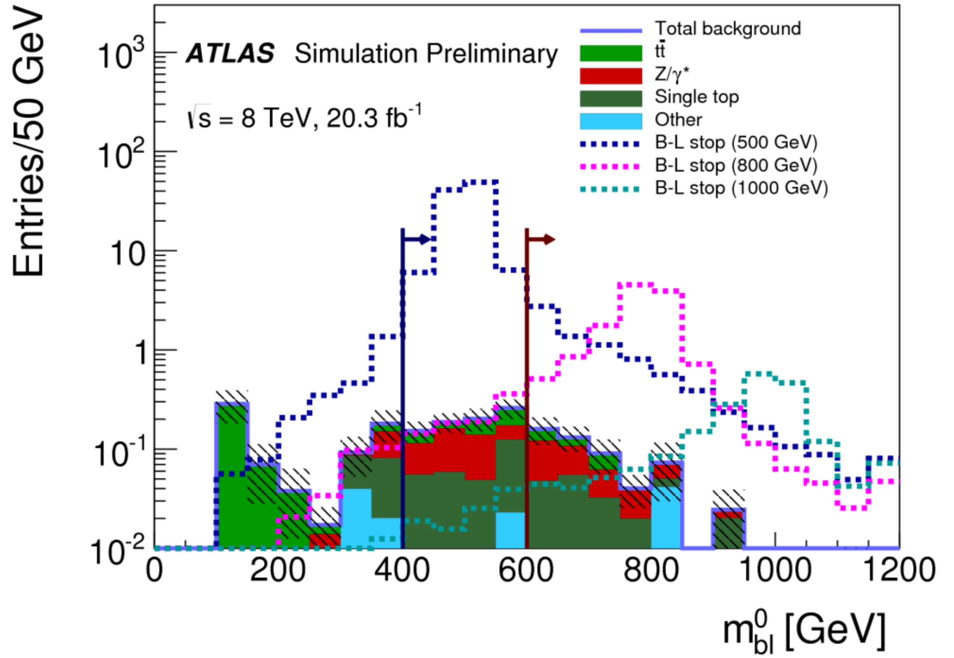
Z. Marshall,
B.A. Ovrut,
A. Purves,
S. Spinner
1402.5434



Summary

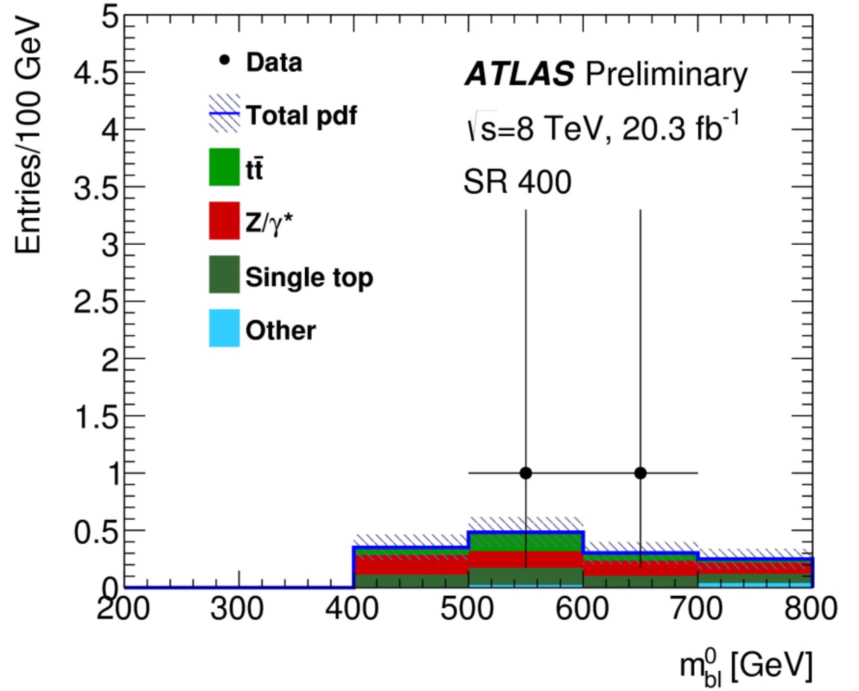
Searched for pair production of scalar top with RPV decay in 20 fb^{-1} of Run 1 ATLAS data at √s=8 TeV

- ➢**Excluded scalar top with mass from 500-1000 GeV for branching fractions of at least 20% to eb or μb**
- ➢**ATLAS-CONF-2015-015**



Plan to search again with Run 2 ATLAS data at √s=13 TeV

- ➢ **15x higher production rate for 1000 GeV mass scalar top**
- ➢ **3x higher top backgrounds**
- ➢ **1.7x higher Z+jets backgrounds**
- ➢**New IBL layer at r=3.3 cm and identification of boosted b-jets**

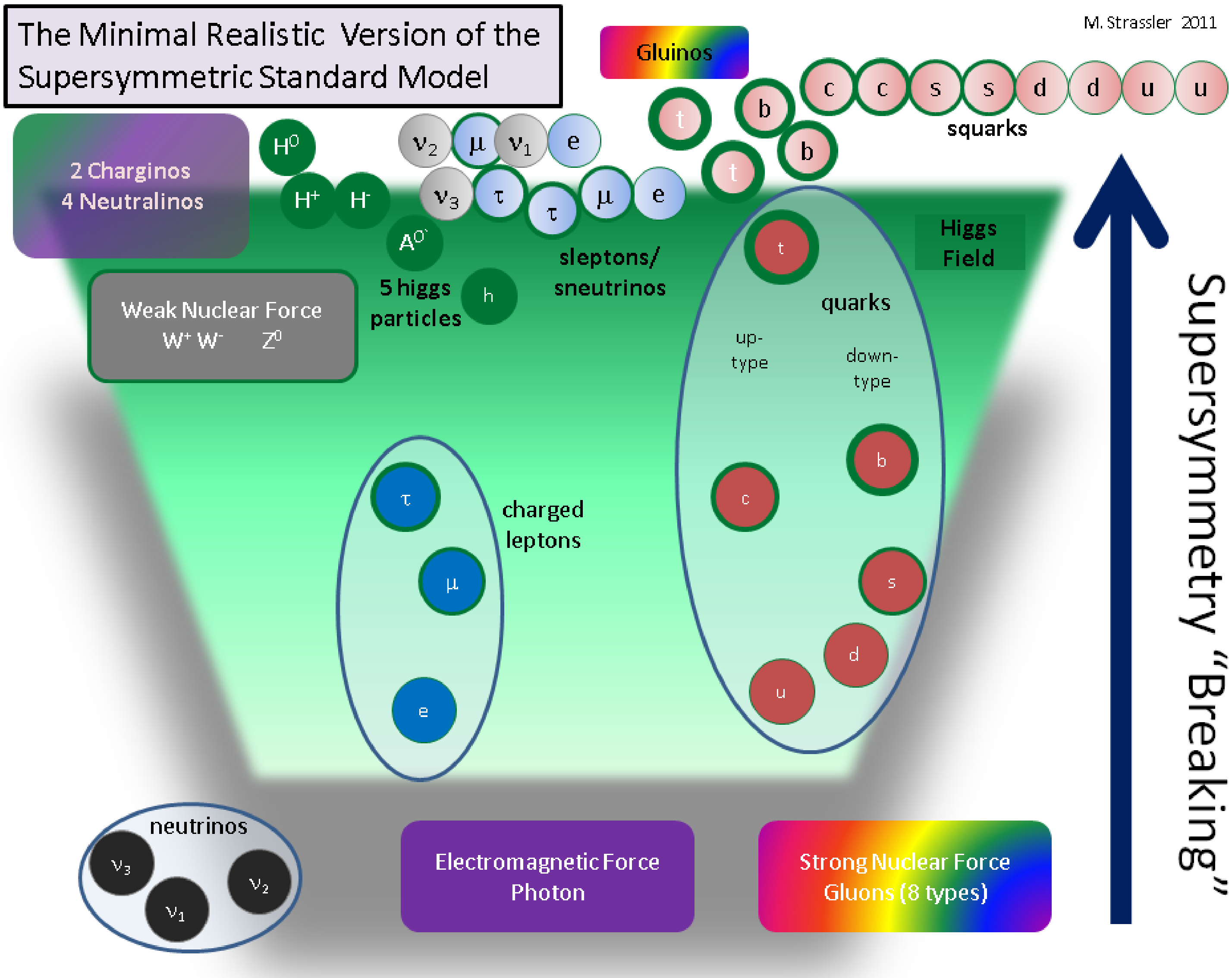


Conventional MSSM

B-L model

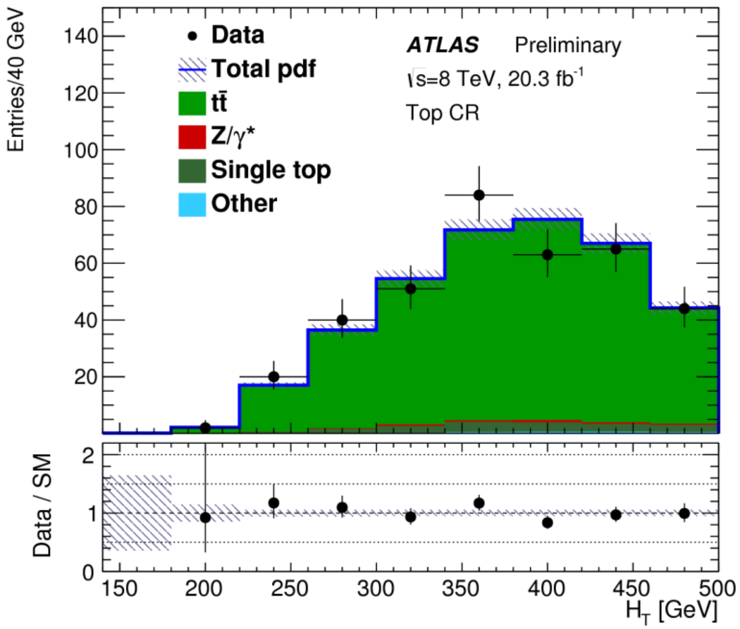
Add RH neutrinos and superpartners

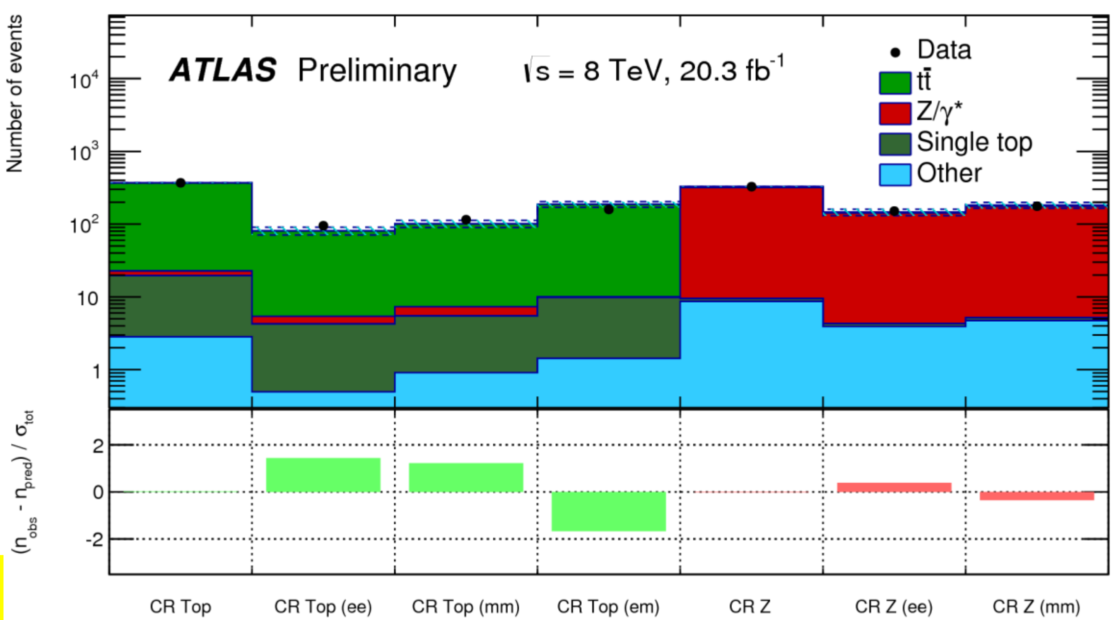
Add new massive B-L gauge boson

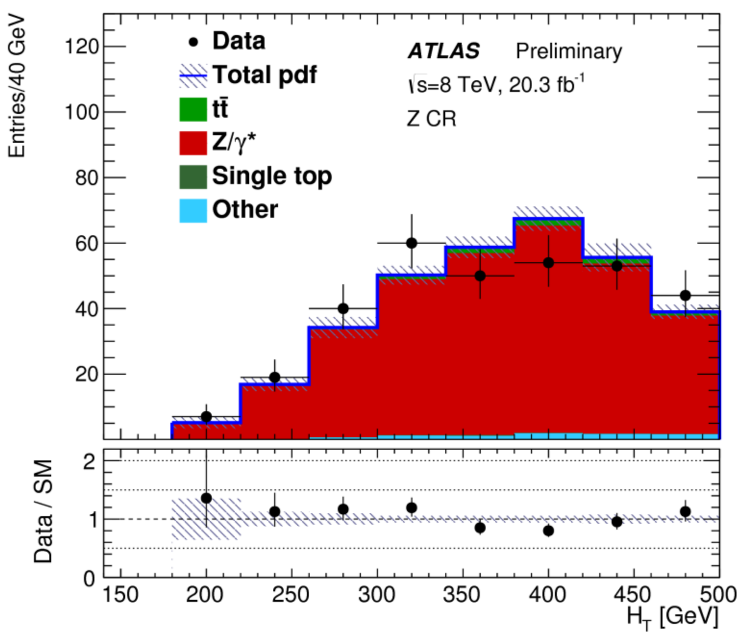


Control regions

➢ **Determine ttbar and Z+jets background levels from dedicated control regions**







Run 1 vs Run 2

Stop mass (GeV)	Pair production xs (fb)	
	√s = 8 TeV	√s=13 TeV
500	86 ± 13	518 ± 69
800	2.9 ± 0.6	28 ± 4
1000	0.44± 0.12	6.4 ± 1.0
1400	-	0.46± 0.10

Inclusive cross sections for signal and backgrounds

BKG	xs (fb)	
	√s = 8 TeV	√s=13 TeV
ttbar	253,000	832,000
$Z/\gamma^* \rightarrow ll$	1122,000	1906,000
Wt	22,000	70,000

Model

- signal with MadGraph+PYTHIA
- ttbar and Wt with POWHEG+PYTHIA
- Z+jets with Sherpa

Stop by M. Kramer et al. 1206.2892, and by C. Borschensky et al. 1407.5066
ttbar from top++ 2.0 by M. Czakon and A. Mitov 1112.5675
Wt by N. Kidonakis 1506.04072 (quoted 173.3 GeV)
Z+jets from FEWZ by C. Anastasiou et al. hep-ph/0312266 (quoted 66-116 GeV)

Results

	SR 600	SR 600 ee	SR 600 $\mu\mu$	SR 600 $e\mu$
Observed	1	0	1	0
Fitted background	0.55 ± 0.15	0.15 ± 0.06	0.24 ± 0.10	0.16 ± 0.06
Fitted $t\bar{t}$	0.10 ± 0.02	0.03 ± 0.01	≤ 0.01	0.07 ± 0.03
Fitted Z/γ^*+jets	0.23 ± 0.12	0.08 ± 0.05	0.15 ± 0.08	≤ 0.01
Single Top	0.18 ± 0.04	0.03 ± 0.01	0.05 ± 0.02	0.09 ± 0.03
Other	0.04 ± 0.01	≤ 0.01	0.04 ± 0.02	≤ 0.01
Input SM	0.47	0.12	0.20	0.16
Input $t\bar{t}$	0.09	0.03	0.00	0.06
Input Z/γ^*+jets	0.16	0.06	0.10	0.00
Input single Top	0.18	0.03	0.05	0.09
Input other	0.04	0.00	0.04	0.00
σ_{vis} [fb]	0.19	0.10	0.20	0.10
Observed $N_{\mathrm{non-SM}}$	3.9	2.1	4.0	2.1
Expected $N_{\mathrm{non-SM}}$	$3.5^{+1.9}_{-1.4}$	$2.6^{+1.6}_{-0.6}$	$3.0^{+1.7}_{-1.0}$	$2.7^{+1.6}_{-0.7}$